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Blatt 2 der Bescheinigung
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ALUMINIUM ALLOY FOR ROLL FORMED PRODUCT AND PROCESS FOR ITS MANUFACTURE

This invention is concerned with an aluminium alloy product of the AA5000 series (of the Aluminium Association Inc. register), and with a process for manufacturing such an aluminium alloy product, and further with the use of such aluminium alloys products in the production of rolled sheet for making corrugated products by means of roll forming for use in structural materials such as in the construction of large welded structures.

For the purpose of this invention sheet material is to be understood as a rolled product having a thickness of not more than 6.0 mm.

Currently large welded structures such as the floor or cargo decks of a ship like a catamaran are built by welding together a large number of extruded sections of standard AA6000-series alloys such as the AA6082 alloy. A typical construction involves fusion welding of a large number of hollow and/or simple sections. Typically hollow sections of the AA6082 alloy are used since this alloy allows the designers to achieve significant weight reductions. This is mainly due to the fact that AA6082 alloy is the strongest of commercially available standard AA6000-series alloys. Because of the limitations imposed by extrudability of the AA6082 alloy, the minimum wall thickness for hollow sections is practically restricted to the range 2.5-4.0 mm depending on the design of the extruded section. This practical limitation on minimum wall thickness in turn limits the weight savings that can be achieved by improving the design.

Alternatively large engineering structures such as cargo or passenger decks of a ship can be constructed by joining pre-fabricated aluminium products produced by joining and/or welding of a number of roll formed corrugated sheets. The realisation of this approach relies on the availability of high strength corrugated aluminium alloy product shapes. This requires aluminium alloy sheets that are not only easy to roll form but also have higher strength. Standard available aluminium alloy feed stock for roll forming such as AA3004 alloy do not develop high enough strength to achieve significant weight reduction.

Within the scope of this invention roll forming, also known as contour roll forming or cold roll forming, is understood to be a continuous process for forming metal from sheet, strip, or coiled stock into desired shapes of essentially uniform thickness by feeding the stock through a series of roll stations equipped with contoured rolls, see Metals Handbook, 9th. edition, Vol.14, ASM International, 1988, pp.624-635.

It is an object of the invention to provide an aluminium alloy feed stock material that combines a 20% higher strength than standard AA3004 alloy with good roll formability at these higher strengths and with good weldability. It is another object of the invention to provide a process of manufacturing an alloy product of the defined composition and desired properties.

According to the invention in one aspect there is provided an aluminium-magnesium alloy having the following composition in weight percent:

Mg	1.5 – 6.0		
Mn	0.3 – 1.4		
Zn	0.4 – 5.0		
Fe	up to 0.5		
Si	up to 0.5		
Zr	up to 0.30		
optionally, one or more of		Cr	0.05 - 0.30
		V	0.05 – 0.25
		Ti	0.01 – 0.20
		Ag	0.05 – 0.40
		Cu	up to 0.40
others	up to 0.05 each, 0.15 total		
Al	balance		

said product being in the form of rolled sheet having a ratio of PS/UTS in the range of 0.4 to 0.9, and good roll formability, in an H-condition or in the O-condition.

PS and UTS stand for 0.2% proof strength and ultimate tensile strength respectively. The H-condition as indicated above is typically an Hxy-condition or modifications thereof, where x is in the range of 1 to 3 and y is in the range of 1 to 6, or modification thereof.

By the invention a surprisingly good combination is achieved of 20% or more higher strength levels than standard AA3004 in soft and strain hardened tempers, a good formability at these higher strength levels and a good weldability. This combination is achieved due to the compositional window and a suitable grain structure. In combination, they provide good bendability, a work hardening index "n" is the range of 0.10 to 0.40 at higher strengths levels of 20% improvement or more than AA3004 in comparable tempers and gauges, and good roll formability having bendability of one times thickness in the Hx6 tempers, with x in the range of 1 to 3, or in the soft temper. The aluminium alloy product is accordance with the invention allows for the production of high strength feed stock for corrugated sheet by means of roll forming. Using corrugated sheet with improved strength levels out of the aluminium alloy product in accordance with the invention, allows for designing and constructing of structures which are lighter than the conventional structures, in particular those based on extruded aluminium alloys. Aluminium alloy products of the defined composition have also been found with good corrosion resistance. This allows the aluminium alloy products to be used in corrosive environments such as a marine environment when applied in a ship or offshore construction.

Roll formability of AA5000 series alloy products may be assessed by means of their bendability performance. Bendability of an material may be tested in accordance with ASTM E-290. During this test a sheet material will be bend for 180o over a mandrel having the same thickness at the sheet material itself; indicated above as bendability of one times thickness. The convex surface of the bend is visually examined for the presence of cracks. The presence of one or more cracks larger than 1 mm indicated a "fail" bendability performance resulting in the sheet material to be rejecting for roll forming. The bendability performance is indicated as "good" in case there are no cracks larger than 1 mm can be seen on the convex surface of the bend.

In a preferred embodiment of the alloy product of the invention the rolled sheet has a ratio of PS/UTS in the range of 0.4 to 0.8, and more preferably in the range of 0.4 to 0.7, to enhance roll formability.

The reasons for the limitations of the alloying elements of the aluminium alloy product according to the present invention are described below. All composition percentages are by weight.

Mg is the primary strengthening element in the alloy. Mg levels below 1.5% do not provide the required strength and when the addition exceeds 6.0% severe cracking occurs during the casting and hot rolling of the product. The preferred level of Mg is between 3.0 to 5.5% as a compromise between fabricability and strength.

Mn is an essential alloying element. In combination with Mg the Mn provides the strength to the alloy product in both welded and non-welded condition. Mn levels below do not provide sufficient strength to the welded joints of the alloy product. Above 1.4% the hot rolling becomes extremely difficult. The preferred maximum limit for Mn is 0.9% which represents a compromise between strength and fabricability. More preferably the ratio Fe/Mn is in the range of 0.3 to1.0.

Zn in an important alloying element since it improves corrosion resistance in the alloy product when it is present in a range of up to 1.2%, preferably up to 0.9%. Further zinc serves as a strengthening element by age hardening in combination with Mg when the Zn is present in a range of 3.0 to 5.0%. In the latter case it is preferred to maintain a Zn/Mg-ratio in the range of 1.1 to 5, and preferably in the range of 4 to 5. When the Zn level is above 5.0% casting and subsequent hot rolling becomes more difficult, in particular at an industrial scale. Below 0.4% the effect of Zn is less significant, so as a consequence a minimum of 0.4% is required.

The Fe in the alloy product may form primary compounds of the Al-Fe-Mn type during casting and thereby limiting the beneficial effects due to the Mn as alloying element. Fe levels above 0.5% causes coarse primary particles formation and which decrease the formability of the alloy product. The preferred range of Fe is 0.15 to 0.30%, more preferably 0.20 to 0.30%.

The Si also combines with Fe to form coarse AlFeSi phase type particles and which can affect the formability of the alloy product. Further Si limits the beneficial effects of Mg. To avoid any unacceptable loss in formability the Si level must be kept below 0.5%. The preferred range for Si is 0.07 to 0.20%, and more preferably 0.10 to 0.20%.

The Zr is an important alloying element for achieving strength improvements. Further the Zr is important to improve the resistance against cracking during welding of the alloy products in accordance with this invention. Zr at a level above 0.3% results in coarse needle shaped primary particles that decrease fabricability of the alloy product and further decrease bendability of the obtained product. As a comprise between strength and formability a preferred range of 0.05 to 0.25% is required.

Ti is important as a grain refiner during solidification of both ingots and welded joints produced using the alloy product in accordance with the invention. However, Ti in combination with Zr can form undesirable coarse primary phases. In order to avoid this the Ti level in the presence of Zr should be kept below 0.2%, and preferably below 0.10%, the most preferred range for Ti is 0.01 to 0.10%.

Cr is an optional alloying element for further improving the corrosion resistance of the alloy product. However, Cr limits the solubility of both Mn and Zr. Therefore, to avoid the formation of coarse primary phases, the Cr level must be kept below 0.3%. A preferred range for Cr is up to 0.15%.

V is an optional alloying element, and may be used to substitute or in addition to Cr. The preferred range is from 0.05 to 0.25%. A more preferred maximum range for V is up to 0.15%.

Cu levels above 0.4% give rise to unacceptable deterioration in the pitting corrosion resistance of the alloy product. The preferred maximum level for Cu is up to 0.25%, and more preferably up to 0.1%.

Silver is an optional alloying element that can improve further the stress corrosion resistance of the alloy product. If added the presence should be limited to 0.4% and the minimum level in the alloy product is preferably at least 0.05%.

The balance is Al and inevitable impurities. Typically each impurity element is present at 0.05% maximum and the total of impurities is 0.15% maximum.

A very successful embodiment of the aluminium alloy product in accordance with the invention is characterised by the following composition in weight percent:

Mg	5.0 – 6.0, preferably 5.0 – 5.6
Mn	0.6 – 1.2
Zn	0.4 – 1.5, preferably 0.4 – 0.9

Zr	0.05 – 0.25
Cr	up to 0.3
Ti	up to 0.2
Fe	up to 0.5, preferably 0.2 – 0.3
Si	up to 0.5, preferably 0.1 – 0.2
Cu	up to 0.4, preferably up to 0.1
Ag	up to 0.4

balance Al and inevitable impurities.

With this embodiment it is achieved that an alloy product is provided which combines a 20% or more higher strength than the standard AA3004 alloy in a comparable gauge and temper, with a good formability at these higher strength levels when assessed by means of bendability in accordance with ASTM E-290, with good weldability, and with a good corrosion resistance. The aluminium alloy product has very good formability in particular at gauges in the range up to 3.0 mm, and more preferably at gauges in the range of 0.2 to 1.0 mm. Further this successful embodiment allows for high speed laser welding, typically in the range of 3 to 10 m/min and preferably in the range of 4 to 6 m/min, for the production of construction panels comprising at least one corrugated sheet made out of the aluminium alloy product as set out above.

In a more preferred embodiment the aluminium alloy product in the O-temper has a minimum 0.2% proof strength (PS) of 110 MPa or more for gauges of up to 3 mm, and more preferably of 115 MPa or more, and most preferably of 120 MPa or more. For gauges of up to 3 mm the aluminium alloy product in the O-temper has a minimum ultimate tensile strength (UTS) of 270 MPa or more, preferably of 280 MPa or more, more preferably of 300 MPa or more, and most preferably of 310 MPa or more.

In a further embodiment of the aluminium alloy product in accordance with this invention the alloy product may be provided with a cladding on at least one side of the surface of the rolled sheet of the following:

(i) it is of a higher purity aluminium alloy than said rolled sheet;

(ii) the cladding is of the Aluminium Association AA1000 series;

(iii) the cladding is of the Aluminium Association AA6000 series;

(iv) the cladding is of the Aluminium Association AA7000 series.

In this embodiment the cladding is brought onto the alloy product prior to roll forming the alloy product into a corrugated profile. The aluminium alloy product is accordance with the invention has a very good corrosion resistance. However, in certain extreme corrosive environments it may be useful to provide a cladding which further enhances to the corrosion resistance of the alloy product. Such clad products utilise a core of the aluminium alloy product of the invention and a cladding of higher purity which in particular corrosion protects the core. The cladding includes essentially unalloyed aluminium or aluminium alloys containing not more than 0.1 or 1% of all other elements. Aluminium alloys herein designated 1xxx-type series include all Aluminium Association (AA) alloys, including the sub-classes of the 1000-type, 1100-type, 1200-type and 1300-type. In addition it has been found that aluminium alloys of the AA6000-series, including the sub-classes, and which contain typically more than 1% of alloying additions, can serve as cladding. And in addition it has been found that aluminium alloys of the AA7000-series, including the sub-classes, and which contain typically more than 0.8% of zinc as alloying element, can serve as cladding, such as AA7072. Other aluminium alloys could also be useful as cladding as long as they provide in particular sufficient overall corrosion protection to the core alloy product.

In a very advantageous embodiment of the alloy product of the invention, the product may be provided with a clad layer of an AA4000-series alloy, such as for example AA4047. In this embodiment the clad layer or layers are not primarily present to provide an improved corrosion resistance, although it may give a contribution, but it allows the alloy product in accordance with the invention to be welded or brazed to another sheet, plate or extrusion product into prefabricated products such as composite metal panels as will be discussed hereafter. In the case of corrugated alloy products clad with AA4000-series alloys, there is no need to provide filler wire during welding in cases where it is otherwise required. Further the structural integrity of the alloy product is maintained, as a consequence higher Zn-levels can be present in the alloy product without affected the corrosion resistance of the heat-affected zone. The thickness of the clad layer should be sufficient to prevent

loss of adhesion from the alloy product and to protect the alloy product from the heat affected zone. In case of brazing, it is possible to braze such clad corrugated sheet with another sheet or plate or extrusion into one piece at a temperature in the range where AA4000-series alloys can be melted. The brazing can be carried out with or without controlled atmosphere.

The clad layer or layers usually much thinner than the core, each constitute 1 to 15 or 20 or possibly 25% of the total composite thickness. A cladding layer more typically constitutes around 5 to 12% of the total composite thickness.

The invention also consists in a corrugated sheet obtained by roll forming an aluminium alloy product as set out above.

In another aspect the invention provides a process for the manufacture of an aluminium alloy product of the defined composition, which process comprises the steps of: (a) casting an ingot, (b) homogenisation and/or preheating of the cast ingot, (c) hot rolling of the homogenised and/or preheated ingot, (d) cold rolling, (e) annealing of the cold rolled sheet at final gauge, and (f) cooling of the annealed sheet at a cooling rate in the range of 10 to 100 °C/hour from annealing heat treatment temperature to below 100°C, in order to achieve a product being in the form of rolled sheet having a ratio of PS/UTS in the range of 0.4 to 0.9, and good roll formability, in an H-condition or in the O-condition.

The homogenisation and/or preheating prior to hot rolling is usually carried out at a temperature in the range 400-560°C in single or in multiple steps. In either case, preheating decreases the segregation of alloying elements in the material as cast. In multiple steps, Zr, Cr and Mn can be intentionally precipitated to control the microstructure of the hot mill exit material. If the treatment is carried out below 400 °C, the resultant homogenisation effect is inadequate. Furthermore, due to substantial increase in deformation resistance of an cast ingot, industrial hot rolling is difficult for temperatures below 400°C. If the temperature is above 560°C, eutectic melting might occur resulting in undesirable pore formation. The preferred time of the above preheat treatment is between 1 and 24 hours.

The hot rolling begins preferably at about 500°C, and is preferably performed down to an intermediate product thickness of up to 5 mm, preferably up to 2mm. In

case, the final feed stock material required for roll forming is a clad material, then roll cladding of the appropriate clad alloy plate is required prior to the hot rolling step. This procedure can be used to produce one sided or double-sided cladding to the alloy product in accordance with the invention. Preferably the cladded or non-cladded product has a minimum hot rolling exit temperature of 300°C. This achieves the effect of an uniform grain structure which in turn is necessary to meet the required bendability of one times thickness. For hot rolling exit temperature of below 300°C, the distribution of the strain hardening in hot rolled product is so non-uniform that it is practically difficult to achieve uniform grain structure and hence the required bendability in the final product.

A 30 to 90% total cold rolling reduction is preferably applied to hot rolled product prior to final annealing, and more preferably a 40 to 90% total cold rolling reduction. In a preferred embodiment the hot rolled product is first initial cold rolled with a cold rolling reduction of 20 to 50%, then intermediate annealed and than cold rolled to final gauge. The intermediate annealing is preferably carried out in a temperature range of 250 to 480°C for a soak time of 15 min. to 10 hours. The intermediate annealing is preferably carried after 20 to 50% cold rolling reduction to distribute the Mg and/or Zn containing intermetallics uniformly in the inter-annealed product. Cold rolling reductions in excess of 90% might cause cracking during rolling.

In a preferred embodiment a minimum of two interannealings during cold rolling prior to final annealing is required. This achieves the effect of not only uniformity in the degree of stretching along the dimensions of roll forming feed stock, but additionally also to obtain good corrosion resistance in the final product. Either a complete absence or only one of the interanneals enhances the tendency of the final product to exfoliate during ASSET testing. Therefore, preferably at least two interanneals are required, preferably carried out after every 20 to 50% cold rolling reduction.

Final annealing after cold rolling can be carried out in cycles of single or multiple steps in one or more of heat-up, hold and cooling down from the annealing temperature. The heat-up period is typically 10min and 10 hours. The annealing temperature is in the range of up to 550°C depending upon the temper. The preferred

range for temperature is of 275 to 480°C to produce the soft temper products, more preferably in the range of 300 to 400°C. A temperature below 275 °C, more preferably in the range of 200 to 250°C, can be used to produce strain hardened and/or stabilised tempers. The soak temperature at the annealing temperature is preferably in the range of 15 min. to 10 hours. The cooling rate following annealing soak to below 100°C is preferably in the range of 10 to 100°C/hour. In case of those aluminium alloy products of the invention which are age hardenable, a solution heat treatment in the range of 350 to 550°C may be applied and an artificial ageing at a temperature in the range of 75 to 250°C. A water or air cooling after the heat treatment can be used.

The resulting rolled sheet is either in an H-temper or in the O-temper, and has good roll formability. Typically up to 3.0 mm, preferably in the range of 0.2 to 1.0 mm gauge sheets of the product alloy can be roll formed to produce corrugated shapes.

The resulting aluminium alloy product can additionally be provided as patterned or embossed sheet.

In another aspect the invention provides a prefabricated panel comprising a corrugated structure obtained by means of roll forming, which corrugated structure comprises at least one aluminium sheet product of the alloy set out above or a sheet product obtained by the process set out above. A prefabricated panel is typically, but not by way of limitation, a composite aluminium panel comprising of two parallel plates and/or sheets secured, for example by means of mechanical fastening elements or adhesion, to the peaks and troughs respectively of a corrugated aluminium stiffener arranged between the parallel plates and/or sheets, wherein the corrugated aluminium stiffener is made out of a roll formed aluminium alloy product of this invention.

In a preferred embodiment the corrugated aluminium stiffener is being secured to a parallel plate or sheet by weld lines extending along the peaks or troughs. The weld lines can be obtained by using any one or combinations of the standard welding techniques, e.g. MIG, TIG, stir welding, friction stir welding, etc. In a further preferred embodiment the weld lines are obtained by laser welding techniques.

Further at least one of the plates or sheets has on the other surface no visible weld lines, but a internal weld line structure where each line of which passes through a trough or peak and into the material of the plate or sheet without however totally penetrating that material. This gives a composite aluminium panel with weld lines on one face and smooth surface on the other face.

In an alternative embodiment the corrugated aluminium stiffener is being secured to a parallel plate or sheet by means of brazing. In this embodiment the corrugated aluminium stiffener is being made from the aluminium alloy product of the invention with a cladding from the AA4000-series alloys, as set out above.

In a preferred embodiment the corrugated aluminium stiffener between the panels has flat peaks and troughs.

Most typically, but not by way of limitation the composite aluminium panel is of a thickness such that the spacing between the external plates and/or sheets lies between 10 and 300 mm, more preferably between 10 and 200 mm. The surface plate/or sheet in such an instance is up to 25 mm thick in typical embodiment, and the corrugated aluminium stiffener is within the range of up to 6 mm thick, preferably up to 3 mm thick, and most preferably in the range of 0.2 to 1.0 mm thickness. By using the aluminium alloy product of the invention at these relatively thin gauges and applied in a composite aluminium panel as set out above, it is achieved that significant weight reduction can be obtained in constructions while maintaining at least the same strength and/or stiffness levels as previously known in the art.

It will be found usually preferable to have the two parallel plates and/or sheets portions each equal to or thicker than the metal thickness of the corrugated aluminium stiffener.

The type of composite aluminium panel defined above can be used alone, for example for bulkheads, or like sub-divisions. However, two or more composite panels can themselves be linked together and form a parallel composite to define for example a hull compartment including sub-divisions or other large-scale metal constructions, such as truck or rail car floors, bridges and especially ships.

The parallel plates or sheet are preferably made out of aluminium alloy, and in case the corrugated aluminium stiffener is welded to a plate or sheet, the plate or

sheet is preferably made of a weldable aluminium alloy. In a more preferred embodiment the plates and/or sheets are within the same compositional window as the corrugated aluminium stiffener obtained from an aluminium alloy product of this invention.

The invention will now be illustrated by several non-limitative embodiments and examples, with reference to the accompanying drawings, in which:

Fig. 1A to 1C show cross-sections of several embodiments of corrugated sheet;

Fig. 2A to 2C show cross-sections of several embodiments of composite aluminium panels;

Fig. 3A and 3B show in cross-sections a composite aluminium panel in connection with I-shaped beams;

Fig. 4 show a perspective view of a composite aluminium panel in connection with an I-shaped beam.

Fig. 1 shows schematically typical shapes of corrugated sheet, as seen in cross-section perpendicular to its direction of elongation, obtained by means of roll forming an aluminium alloy product in accordance with the invention. The corrugated sheet can be used as a stiffener sheet in a composite aluminium panel. Fig. 1A and 1B show flat peaks and troughs, and where Fig. 1B has a dovetail shape. An alternative embodiment is shown in Fig.1C where the corrugated sheet has curved peaks and troughs. The indicated dimensions a, b, c, and d are typically in the range of 10 to 300 mm.

Fig. 2A and 2B show schematically, as seen in cross-section perpendicular to its direction of elongation, composite aluminium panels of the invention where a corrugated aluminium stiffener is arranged between two parallel sheets and/or plates. The embodiment of Fig. 2C shows schematically, as seen in cross-section perpendicular to its direction of elongation, a composite aluminium panel where the corrugated aluminium stiffener comprises two corrugated sheets each with flat peaks and troughs and whereby the peak of one sheet is joined to the trough of the other corrugated sheet. The arrows in Figs. 2A to 2C show the location of weld lines for securing the various sections to each other.

Fig. 3A and 3B show schematically, as seen in cross-section perpendicular to its direction of elongation, a composite aluminium panel of the invention being secured to I-shaped beams or profiles by means of securing at least one of the parallel plates or sheet of the composite aluminium panel to the I-shaped beam.

Fig. 4 show schematically a perspective view of composite aluminium panels are connected to each other in their direction of elongation. For this the following procedure can de used: firstly produce a section which fits with the contours of the corrugated shape, secondly open the top plating to expose the corrugated shape, thirdly place a "connecting corrugated section" on to the panels to be joined such that the "connecting corrugated section" is equally partitioned between the two sandwich panels, then join at those points marked as "xxxx" in the figure. The above procedure then securely fastens any two sandwich panels of current invention along the width direction. Alternatively sandwich panels can be produced in such away that one of the two top plates can be shorter than the other to allow ease of joining along the width direction.

Example 1

An alloy within the compositional range of the invention, having the following chemical composition (in weight percent): 5.20% Mg, 0.84% Mn, 0.50% Zn, 0.13% Zr, 0.013% Cu, 0.049% Cr, 0.19% Fe, 0.11% Si, 0.015% Ti, balans aluminium and inevitable impurities, has been DC-cast on an industrial scale to an ingot having dimensions of 440x1480x4800 mm. The ingot has been preheated for 15 hours at 510°C, then hot rolled at about 500°C to produce 4mm gauge products. Prior to subsequent cold reduction, an intermediate anneal at 350°C for a period of 2 hours has been applied. The annealed and hot rolled product was subsequently cold rolled to 2mm gauge sheet. A second interanneal has been applied at 350°C for a period of 2 hours. Followed by cold rolling to a final gauge of 1.0 mm and then final annealed with similar conditions as the interannealing in order to produce a soft temper product.

The material has been assessed in accordance with EURO-norm 10,002 for its tensile properties in the LT-direction. Further the material has been assessed for its

formability by testing the bendality in accordance with ASTM E-290. During this bendability test 1.0 mm gauge sheet material of 120x45mm has been bent for 180° over a mandrel with the same thickness as the sheet material, viz. 1.0mm. The bent specimens have been visually examined for the appearance of cracks on the convex surface of the bend. The outcome of this test is indicated by specifying good or fail. By the term "fail" it is indicated that there was at least one crack of 1mm or more on the convex surface of the bend.

The results are listed in Table 1 where an comparison has been made with samples of standard AA3004 material in the O-temper. From these results it can be seen that the aluminium alloy product in accordance with this invention has a more than 20% higher strength level than AA3004 material in the same temper and with the same gauge, in this particular case an improvement of more than 45% has been achieved, while the bendability is at least equivalent to standard AA3004.

Table 1

Material	Temper	Gauge [mm]	0.2% PS [MPa]	UTS [MPa]	Elong. [%]	Bendability
Invention	0	1.0	132	315	20.1	good
			135	316	20.3	good
			129	314	19.9	good
			131	316	20.7	good
AA3004	0	1.0	65	157	14.0	good
			67	158	14.5	good
			69	155	14.3	good
			66	159	14.2	good

Example 2

Sheet material with dimensions of 1200x250mm and of 1.0 mm thickness of standard AA3004 and material identical to the material of Example 1, both materials were in the O-temper, were subjected a welding testing. Two identical sheets were welded together using a 12 kW CO_2 laser equipment, operating at 6 kW and with a line speed of 5 m/min. Tensile samples with weld beads were produced from such "through welded" sheets and tested for tensile properties.

The results are listed in Table 2. From these results it can be seen that after welding the aluminium product in accordance with the invention has at least 20% higher tensile properties than standard AA3004 material at similar gauges and temper. Further this example shows that the product of this invention may be welded at very thin gauges using laser techniques at relatively high welding line speeds. Further it has been found that when the base material is in the O-temper, the properties of the base material are essentially responsible for the mechanical properties after welding and not the welding technique applied. This can also be found from the results as listed in Table 1 and 2 where the material in accordance with the invention have mechanical properties in the same range.

Table 2

Material	0.2% PS [MPa]	UTS [MPa]	Elongation [%]
invention	132	315	20.1
	136	316	20.3
	131	314	19.9
AA3004	66	155	13.1
	69	152	14.2
	66	158	14.5

Example 3

Using the same processing route as with Example 1 sheet material in accordance with the invention and having the same chemical composition has been produced with a final gauge of 1.3mm. Then two different final annealing treatment have been applied, after which the tensile properties have been determined in accordance with EURO-norm 10,002 in both the L- and LT-direction. The two final anneals applied were: (1) soak time of 1 hour at 250°C; and (2) soak time of 1 hour at 350°C. In both cases the heating up rate was 25°C/hour and the cooling rate to below 100°C after final annealing was 10°C/hour. Annealing of type (1) results in an H-temper and of type (2) results in an O-temper. The results are listed in Table 3. From these results it can be seen that the aluminium alloy product in accordance with the invention can be

provided in the O-temper and in an H-temper, in both cases having strength levels of at least 20% improvement over standard AA3004 material.

Table 3

Annealing type	Gauge [mm]	L-direction			LT-direction		
		PS [MPa]	UTS [MPa]	Elong. [%]	PS [MPa]	UTS [MPa]	Elong. [%]
(1)	1.3	252 254	370 372	9.6 11.0	254 255	370 371	12.3 12.5
(2)	1.3	128 128	317 318	14.7 15.9	126 127	311 314	20.2 19.9

CLAIMS

1. An aluminium alloy product of composition (in weight percent):

Mg	1.5 – 6.0		
Mn	0.3 – 1.4		
Zn	0.4 – 5.0		
Fe	up to 0.5		
Si	up to 0.5		
Zr	up to 0.30		
optionally, one or more of		Cr	0.05 - 0.30
		Ti	0.01 – 0.20
		V	0.05 – 0.25
		Ag	0.05 - 0.40
		Cu	up to 0.40
others	up to 0.05 each, 0.15 total		
Al	balance		

said product being in the form of rolled sheet having a ratio of PS/UTS in the range of 0.4 to 0.9 and good roll formability, in an H-condition or in the O-condition.

2. An aluminium alloy product in accordance with claim 1, wherein the Zn content is in the range of 0.4-1.2 %.

3. An aluminium alloy product in accordance with claim 1, wherein the Zn content is in the range of 3.0-4.5%.

4. An aluminium alloy in accordance with claims 1 or 2, wherein the aluminium alloy product has the following composition:

Mg	5.0 - 6.0
Mn	0.6 - 1.2
Zn	0.4 - 1.5

Zr	0.05 - 0.25
Cr	up to 0.3
Ti	up to 0.2
Fe	up to 0.5
Si	up to 0.5
Cu	up to 0.4
Ag	up to 0.4

balance Aluminium and inevitable impurities.

5. An aluminium alloy product in accordance with any one of claims 1 to 4, wherein the product is a sheet with a final gauge in the range of 0.2 to 1.0 mm.

6. An aluminium alloy product in accordance with any one of claims 1 to 5, wherein a cladding is present on at least one side of the surface of the rolled sheet of the following:
   (i) it is of a higher purity aluminium alloy than said rolled sheet;
   (ii) the cladding is of the Aluminium Association AA1000 series;
   (iii) the cladding is of the Aluminium Association AA6000 series;
   (iv) the cladding is of the Aluminium Association AA4000 series;
   (v) the cladding is of the Aluminium Association AA7000 series.

7. A corrugated sheet obtained by roll forming an aluminium alloy product in accordance with any one of claims 1 to 6.

8. A process of manufacturing an aluminium alloy product in accordance with any one of claims 1 to 6, comprising the steps of:
   (a) casting;
   (b) homogenisation and/or preheating;
   (c) hot rolling;
   (d) cold rolling;
   (e) annealing;

(f) cooling at a rate of 10 to 100 °C/hour from annealing heat treatment temperature to below 100°C.

9. A process in accordance with claim 8, wherein homogenisation and/or preheating is performed at 400 to 560 °C for 1 to 24 hours; hot rolling is performed down to a product thickness of up to 2 mm; and cold rolling is performed to reduce product thickness by 30 to 90%, preferably 40 to 90%.

10. A process in accordance with claim 9, wherein the cold rolling is performed by an initial cold rolling to reduce product thickness by 20 to 50%, followed by inter-annealing at 250 to 560°C for 15 min to10 hours, and final cold rolling to reduce product thickness in total by 20 to 90%, preferably 40 to 90%.

11. A composite aluminium panel comprising two parallel plates and/or sheets secured to the peaks and troughs of a corrugated aluminium stiffener sheet between the parallel plates and/or sheets, wherein the corrugated aluminium stiffener sheet is made from the aluminium alloy product according to any one of claims 1 to 6 or obtained from the process in accordance with any one of claims 8 to 10.

12. A composite aluminium panel according to claim 11, wherein the corrugated aluminium stiffener sheet has a thickness in the range of 0.2 to 1.0 mm.

ABSTRACT

The invention is concerned with an aluminium alloy product of composition (in weight percent): 1.5 – 6.0% Mg, 0.3 – 1.4% Mn, 0.4 – 5.0% Zn, up to 0.5% Fe, up to 0.5% Si, up to 0.30% Zr, and optionally, one or more of (0.05-0.30% Cr, 0.01–0.20% Ti, 0.05-0.25% V, 0.05 -0.40% Ag, up to 0.40% Cu), others up to 0.05 each, 0.15 total, aluminium balance, said product being in the form of rolled sheet having a ratio of PS/UTS in the range of 0.4 to 0.9 and good roll formability, in an H-condition or in the O-condition. Further the invention is concerned with a process for manufacturing such an aluminium alloy product, and further with the use os such aluminium alloy products in the production of rolled sheet for making corrugated products by means of roll forming for use in structural materials such as in the construction of large welded structures.

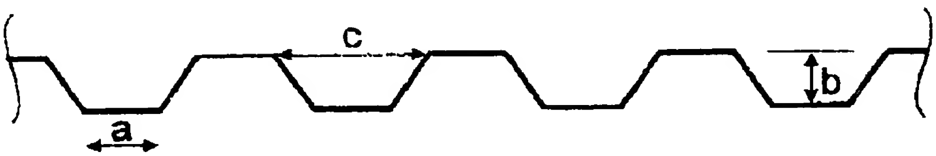

Fig. 1A

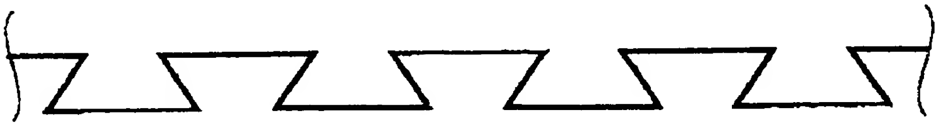
Fig. 1B

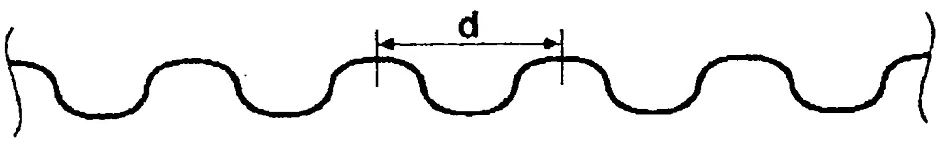

Fig. 1C

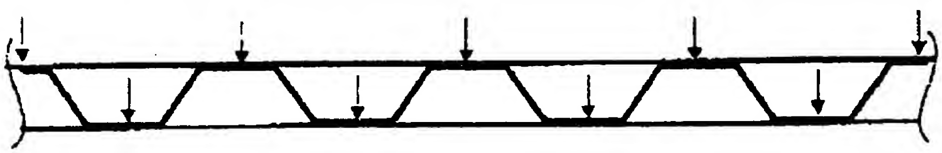
Fig. 2A

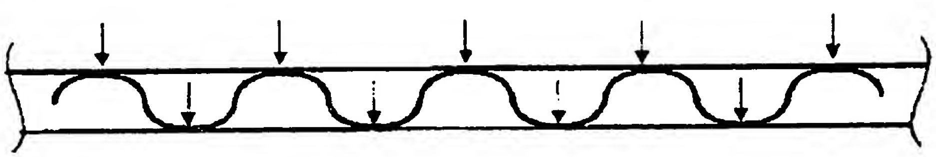
Fig. 2B

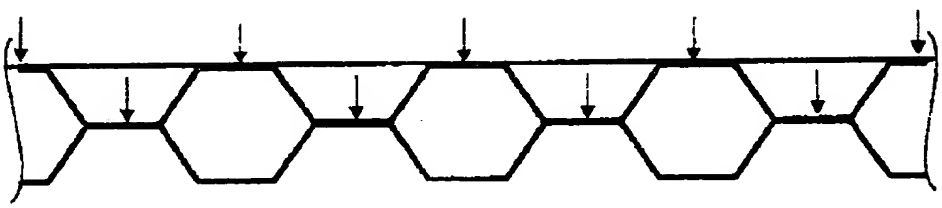
Fig. 2C

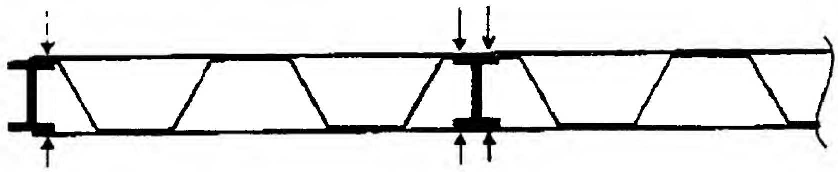

Fig. 3A

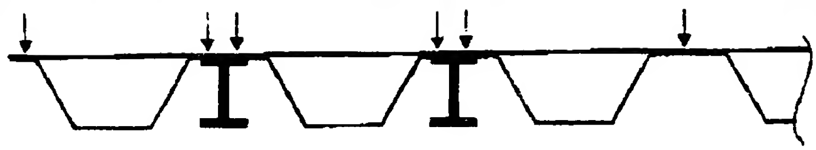

Fig. 3B

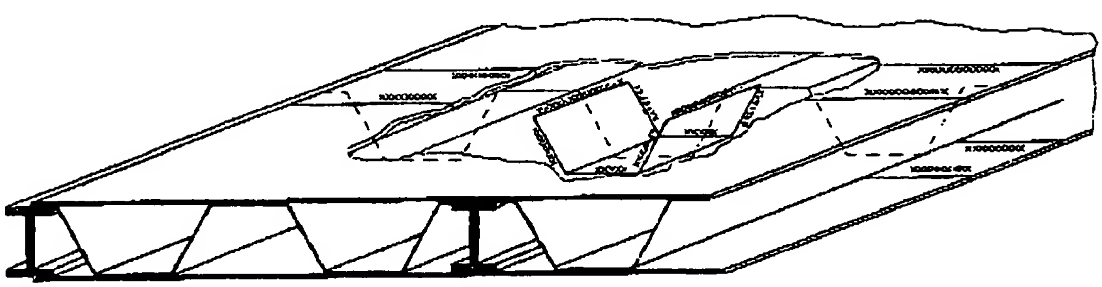

Fig. 4